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ASTRONOMY.—*The distances of the heavenly bodies.*[1] W. A. EICHELBERGER, U. S. Naval Observatory.

A year ago our retiring president took the members of the Society into his confidence as follows:

> Cognizant of the fact that my election to the presidency of the Philosophical Society a year ago, obligated me to give an address of some sort one year later, I confidently waited for the inspiration that I felt would suggest a fitting subject for the occasion. The expected inspiration did not, however, materialize.

Undoubtedly because of that fact, and out of the goodness of his heart, towards the close of his address he turned to the present speaker, then presiding, and said:

> I have said nothing whatever about the determination of the distances between the planets nor of the units used by astronomers in reckoning distances of the stars. . . . They form, so to speak, other chapters of the subject which I shall leave to some future ex-president of our Society.

This call, I suppose, was intended to take the place of an inspiration, and wherever I have gone during the past twelve months the call has ever been ringing in my ears. The subject of the evening is presented therefore not as a matter of choice but from compulsion.

Before any attempt was made by the ancients to determine the distance from the Earth of any celestial body, we find them

[1] Presidential address before the Philosophical Society of Washington on March 4, 1916.

arranging these bodies in order of distance very much as we know them to-day, assuming that the more rapid the motion of a body among the stars the less its distance from the Earth; the stars, that were supposed to have no relative motions, were assumed to be the most distant objects.

The first attempt to assign definite relative distances to any two of the bodies was probably that of Eudoxus of Cnidus who, about 370 B.C., supposed, according to Archimedes, that the diameter of the Sun was nine times greater than that of the Moon, which is equivalent to saying that, since the Sun and the Moon have approximately the same apparent diameter, the distance of the Sun from the Earth is nine times greater than that of the Moon.

A century later, about 275 B.C., Aristarchus of Samos gave a method of determining the relative distances of the Sun and Moon from the Earth as follows: When the Moon is at the phase first quarter or last quarter, the Earth is in the plane of the circle which separates the portion of the Moon illuminated by the Sun from the non-illuminated part, and the line from the observer to the center of the Moon is perpendicular to the line from the center of the Moon to the Sun. (Diagram shown.) If, at this instant, the angular separation of the Sun and Moon is determined, one of the acute angles of a right-angle triangle—Sun, Moon, and Earth—is known, from which can be deduced the ratio of any two of the sides, as, for instance, the ratio of the distance from the Earth to the Moon to that from the Earth to the Sun. Aristarchus gives the value of this angle as differing from a right angle by only one-thirtieth of that angle, i.e. it is an angle of 87°, from which it follows that the distance from the Earth to the Sun is nineteen times that from the Earth to the Moon. This method of Aristarchus is theoretically correct, but in determining the angle at the Earth as being 3° less than a right angle, he made an error of about 2° 50′.

Hipparchus, who lived about 150 B.C. and was called by Delambre the true father of astronomy, attacked the problem of the distances of the Sun and Moon through a study of eclipses. Assuming in accordance with the result of Aristarchus that the

Sun is nineteen times as far from the Earth as the Moon, having determined the diameter of the Earth's shadow at the distance of the Moon and knowing the angular diameter of the Moon he found 3′ as the Sun's horizontal parallax. By the Sun's parallax is meant the angle at the Sun subtended by the Earth's semi-diameter and if a = the semi-diameter of the Earth, Δ = the distance to the Sun, and Π = Sun's horizontal parallax, the relation (diagram shown) between these quantities is expressed by the equation:

$$\text{Sin } \Pi = \frac{a}{\Delta}$$

The next attempt to determine the distance of a heavenly body was made about 150 A.D. by Claudius Ptolemy, the last of the ancient astronomers and one whose writings were considered the standard in things astronomical for fifteen centuries. To determine the lunar parallax he resorted to direct observations of the zenith distance of the Moon on the meridian, comparing the result of his observations with the position obtained from the lunar theory. He determined the parallax when the Moon was nearest the zenith, and also when it crossed his meridian at its farthest distance from the zenith. From his observations he obtained results varying from less than 50 per cent of the true parallax (57′.0) to more than 150 per cent of that value. According to Houzeau the definitive result of Ptolemy's work is 58′.7.

It is thus seen that the astronomers of two thousand years ago had a fairly accurate knowledge of the distance of the Moon from the Earth, but an entirely erroneous one of the distance of the Sun, the true distance being something like twenty times that assumed by them. This value of the distance of the Sun from the Earth was accepted for nineteen centuries from Aristarchus to Kepler, having been deduced anew by such men as Copernicus and Tycho Brahe.

With the announcement by Kepler, early in the seventeenth century, of his laws of planetary motion, it became possible to deduce from the periodic times of revolution of the planets around

the Sun their relative distances from that body, and thus to determine the distance of the Sun from the Earth, by determining the distance or parallax of one of the planets.

From observations of Mars, Kepler obtained the distance of the Sun from the Earth as about three times that accepted up to his time. His value, however, was but one-seventh of the true distance. About fifty years later Flamsteed and Cassini working independently and using the same method as that employed by Kepler obtained for the first time approximately the correct value of the distance of the Sun from the Earth. In a letter, dated November 16, 1672, to the Publisher of the *Philosophical Transactions*, Flamsteed says:

> September last I went to Townley. The first week that I intended to have observed ♂ there with Mr. Townley, I twice observ'd him, but could not make two Observations, as I intended, in one night. The first night after my return, I had the good hap to measure his distances from two Stars the same night; whereby I find, that the Parallax was very small; certainly not 30 seconds: So that I believe the Sun's Parallax is not more than 10 seconds. Of this Observation I intend to write a small Tract, when I shall gain leisure; in which I shall demonstrate both the Diameter and Distances of all the Planets by Observations; for which I am now pretty well fitted.

During the two and a half centuries since Flamsteed's determination there have been more than a hundred determinations of the solar parallax by various methods. In the method used by Flamsteed, the rotation of the Earth is depended upon to change the relative position of the observer, the center of the Earth, and Mars. (Diagram shown.) Another method is to establish two stations widely separated in latitude, and in approximately the same longitude. At one station, the zenith distance of Mars will be determined as it crosses the meridian north of the zenith; at the other station, the zenith distance will be determined as it crosses the meridian south of the zenith. The sum of the two zenith distances minus the difference in latitude between the two stations will give the displacement of Mars due to parallax. These two methods have been successfully applied to several of the asteroids whose distances from the Sun are very nearly that of Mars.

The nearest approach of Venus to the Earth is during her transit across the face of the Sun, and these occasions, four during the last two centuries, have been utilized to determine the solar parallax. Here as in the case of Mars two different methods may be used, either by combining observations at two stations widely separated in latitude, or at two stations widely separated in longitude. (Diagrams shown.)

The methods just described for obtaining the solar parallax, the geometrical methods, were made available, as has been said, by the discovery of Kepler's laws of planetary motion. Newton's discovery of the law of gravitation gave rise to another group of methods, designated as gravitational methods. The best of these is probably that in which the distance of the Sun from the Earth is determined from the mass of the Earth, which, in turn, is determined from the perturbative effect of the Earth upon Venus and Mars. This method is long and laborious but its importance lies in the fact that the accuracy of the result increases with the time. Professor C. A. Young says:

> this is the "method of the future," and two or three hundred years hence will have superseded all the others,—unless indeed it should appear that bodies at present unknown are interfering with the movements of our neighboring planets, or unless it should turn out that the law of gravitation is not quite so simple as it is now supposed to be.

A third group of methods of determining the distance of the Sun from the Earth, called the physical methods, depends upon the determination of the velocity of light in conjunction either with the time it takes light to travel from the Sun to the Earth obtained from observations of the eclipses of Jupiter's satellites, or with the constant of aberration derived from observations of the stars.

In August, 1898, Dr. Witt of Berlin discovered an asteroid, since named Eros, which was soon seen to offer exceptional opportunity for the determination of the solar parallax, as at the very next opposition, in November, 1900, it would approach to within 30,000,000 miles of the Earth. At the meeting of the Astrographic Chart Congress in Paris in July, 1900, it was resolved to seize this opportunity and organize an international

parallax campaign. Fifty-eight observatories took part in the various observations called for by the general plan. The meridian instruments determined the absolute position of Eros from night to night as it crossed the meridians of the various observatories; the large visual refractors measured the distance of Eros from the faint stars near it, at times continuing the measures throughout the entire night; and the photographic equatorials obtained permanent records of the position of Eros among the surrounding stars. In addition long series of observations had to be made to determine the positions of the stars to which Eros was referred.

When several years had elapsed after the completion of the observations, and no general discussion of all the material had been provided for, Prof. Arthur R. Hinks of Cambridge, England volunteered for the work. The undertaking was truly monumental. He first formed a catalogue of the 671 stars which had been selected by the Paris Congress for observation as marking out the path of Eros from a discussion of the results obtained by the meridian instruments and from the photographic plates. This done, with these results as a basis, a larger catalogue of about 6000 stars had to be formed from measures on the photographic plates. He was then ready to commence the discussion of the observations of Eros itself. From 1901 to 1910 there appeared in the *Monthly Notices of the Royal Astronomical Society* eight articles covering 135 pages giving the results of his labors.

From a discussion of all the photographic observations he obtained a solar parallax of

$$8''.807 \pm 0''.0027$$

a probable error equivalent to an uncertainty of about 30,000 miles in the distance to the Sun.

From a discussion of all the micrometric observations he obtained

$$8''.806 \pm 0''.004$$

The observations with the meridian instruments gave

$$8''.837 \pm 0''.0185$$

a determination relatively much weaker than either of the others.

A parallax of 8″.80, the value adopted for all the national almanacs twenty years ago, corresponds to a distance of 92,900,000 miles. At present it seems improbable that another parallax campaign will be undertaken before 1931, when Eros approaches still nearer to the Earth, its least distance at that time being about 15,000,000 miles.

TABLE I

APPROXIMATE DISTANCE FROM EARTH TO SUN AS ACCEPTED AT VARIOUS TIMES

DATE	DISTANCE
	miles
275 B.C. to 1620 A.D.	4,500,000
1620 Kepler	13,500,000
1672 Flamsteed	81,500,000
1916	92,900,000

When Copernicus proposed that the Sun is the center of the Solar System and that all the planets including the Earth revolve around the Sun, it was at once seen that such a motion of the Earth must produce an annual parallax of the stars. Tycho Brahe rejected the Copernican System because he could not find from his observations any such parallax. However, the system was generally accepted as the true one and the determination of stellar parallax or the distance of the stars became a live subject. Picard in the latter half of the seventeenth century, using a telescope and a micrometer in connection with his divided circle, showed an annual variation in the declination of the pole star amounting to 40″. In 1674 Hooke announced a parallax of 15″ for γ Draconis. About this same time Flamsteed announced a parallax of 20″ for α Ursae Minoris, but J. Cassini showed that the variations in the declination did not follow the law of the parallax.

The period which we have now reached is so admirably treated by Sir Frank W. Dyson, Astronomer Royal, in his Halley Lec-

ture delivered at Oxford on May 20, 1915, that I ask your indulgence while I quote rather freely from that source.

> Thus in Halley's time, it was fairly well established that the stars were at least 20,000 or 30,000 times as distant as the sun. Halley did not succeed in finding their range, but he made an important discovery which showed that three of the stars were at sensible distances. In 1718 he contributed to the Royal Society a paper entitled Considerations of the Change of the Latitude of Some of the Principle Bright Stars. While pursuing researches on another subject, he found that the three bright stars—Aldebaran, Sirius, and Arcturus—occupied positions among the other stars differing considerably from those assigned to them in the *Almagest* of Ptolemy. He showed that the possibility of an error in the transcription of the manuscript could be safely excluded, and that the southward movement of these stars to the extent of 37′, 42′, and 33′,—i.e. angles larger than the apparent diameter of the sun in the sky—were established. . . .
>
> This is the first good evidence, i.e. evidence which we now know to be true, that the so called fixed stars are not fixed relatively to one another. It is the first positive proof that the distances of the stars are sensibly less than infinite.

At the time of the appearance of Halley's paper there was coming into notice a young astronomer, James Bradley, then 26 years old. He was admitted to membership in the Royal Society the same year that Halley's paper was presented. He was exceedingly eager to attack the problem of the distances of the stars. At length the opportunity presented itself. To quote again from Sir Frank Dyson:

> Bradley designed an instrument for measuring the angular distance from the zenith, at which a certain star, γ Draconis, crossed the meridian. This instrument is called a zenith sector. The direction of the vertical is given by a plumb-line, and he measured from day to day the angular distance of the star from the direction of the vertical. From December, 1725, to March, 1726, the star gradually moved further south; then it remained stationary for a little time; then moved northwards until, by the middle of June, it was in the same position as in December. It continued to move northwards until the beginning of September, then turned again and reached its old position in December. The movement was very regular and evidently not due to any errors in Bradley's observations. But it was most unexpected. The effect of parallax—which Bradley was looking for—would have brought the star farthest south in December, not in March. The times were all three months wrong. Bradley examined other stars. thinking first that this might be due to a movement of the earth's

pole. But this would not explain the phenomena. The true explanation, it is said, although I do not know how truly, occurred to Bradley when he was sailing on the Thames, and noticed that the direction of the wind, as indicated by a vane on the mast-head, varied slightly with the course on which the boat was sailing. An account of the observations in the form of a letter from Bradley to Halley is published in the *Philosophical Transactions* for December, 1728:

> When the year was completed, I began to examine and compare my observations, and having pretty well satisfied myself as to the general laws of the *phenomena*, I then endeavored to find out the cause of them. I was already convinced that the apparent motion of the stars was not owing to the nutation of the earth's axis. The next thing that offered itself was an alteration in the direction of the plumb-line with which the instrument was constantly rectified; but this upon trial proved insufficient. Then I considered what refraction might do, but there also nothing satisfactory occurred. At length I conjectured that all the *phenomena* hitherto mentioned, proceeded from the progressive motion of light and the earth's annual motion in its orbit. For I preceived that, if light was propagated in time, the apparent place of a fixed object would not be the same when the eye is at rest, as when it is moving in any other direction than that of the line passing through the eye and the object; and that, when the eye is moving in different directions, the apparent place of the object would be different.

When Bradley's observations of γ Draconis were corrected for aberration, they showed, according to himself, that the parallax of that star could not be as much as $1''.0$, or that the star was more than 200,000 times as distant from the Earth as the Sun.

On December 6, 1781 there was read before the Royal Society a paper by Mr. Herschel, afterwards Sir William, on the *Parallax of the Fixed Stars*. We read:

> The method pointed out by Galileo, and first attempted by Hook, Flamstead, Molineaux, and Bradley, of taking distances of stars from the zenith that pass very near it, though it failed with regard to parallax, has been productive of the most noble discoveries of another nature. At the same time it has given us a much juster idea of the immense distance of the stars, and furnished us with an approximation to the knowledge of their parallax that is much nearer the truth than we ever had before. . . .
>
> In general, the method of zenith distances labours under the following considerable difficulties. In the first place, all these distances, though they should not exceed a few degrees, are liable to refractions; and I hope to be pardoned when I say that the real quantities of these refractions, and their differences, are very far from being perfectly known. Secondly, the change of position of the earth's axis arising from nutation, precession of the equinoxes, and other causes, is so far from being completely settled, that it would not be very easy to say what it exactly is at any given time. In the third place, the aber-

ration of light, though best known of all, may also be liable to some small errors, since the observations from which it was deduced laboured under all the foregoing difficulties. I do not mean to say, that our theories of all these causes of error are defective; on the contrary, I grant that we are for most astronomical purposes sufficiently furnished with excellent tables to correct our observations from the above mentioned errors. But when we are upon so delicate a point as the parallax of the stars; when we are investigating angles that may, perhaps, not amount to a single second, we must endeavour to keep clear of every possibility of being involved in uncertainties; even the hundredth part of a second becomes a quantity to be taken into consideration.

Herschel then proceeds to advocate selecting pairs of stars of very unequal magnitude and whose distance apart is less than five seconds, and making very accurate micrometric measures of this distance from time to time. The first condition, should give, in general, stars very unequally distant from the Earth, so that the changing perspective as the Earth revolves in her orbit would give a variation of the apparent distance between the stars, while the small distance, less than five seconds, would eliminate from consideration entirely any effect upon this distance of the uncertainties in refraction, precession, nutation, aberration, etc. Herschel had already commenced the cataloguing of such double stars and in January, 1782, submitted to the Royal Society a catalogue of 269. This work did not enable Herschel to determine the distances of the stars but did enable him to demonstrate that there exist pairs of stars in which the two components revolve the one around the other. In twenty years he had found fifty such pairs.

Coming forward another generation, that is, to a time a little less than a hundred years ago, we find Pond, then Astronomer Royal, writing:

The history of annual parallax appears to me to be this: in proportion as instruments have been imperfect in their construction, they have misled observers into the belief of the existence of sensible parallax. This has happened in Italy to astronomers of the very first reputation. The Dublin instrument is superior to any of a similar construction on the continent; and accordingly it shows a much less parallax than the Italian astronomers imagined they had detected. Conceiving that I have established, beyond a doubt, that the Greenwich instrument approaches still nearer to perfection, I can come to no other conclusion than that this is the reason why it discovers no parallax at all.

Within fifteen years after this statement by Pond, observations had been obtained which showed a measurable parallax of three different stars. The announcements of these results, each by a different astronomer, were practically simultaneous.

W. Struve, using a filar micrometer, determined the distance of α Lyrae from a small star about 40″ distant on 60 different days over a period of nearly three years. He obtained a parallax of $0''.262 \pm 0''.025$. Bessel, using his heliometer, determined the distances of 61 Cygni from two small stars distant about 500″ and 700″ respectively. He obtained for this star a parallax of $0''.314 \pm 0''.020$. Henderson, using determinations of the position of α Centauri by meridian instruments, deduced a parallax of $1''.16 \pm 0''.11$. All three of these results were announced in the winter of 1838–39, and indicate that the three stars are distant from the Earth about 750,000, 650,000, and 200,000 times the distance of the Sun from the Earth.

TABLE II

PARALLAX OF 61 CYGNI

MEAN DATE	OBSERVED DISPLACEMENT	COMPUTED FROM 0″.314
1837 August 23	+0″.20	+0″.18
September 14	+0.10	+0.08
October 12	+0.04	−0.05
November 22	−0.21	−0.22
December 21	−0.32	−0.27
1838 January 14	−0.38	−0.27
February 5	−0.22	−0.23
May 14	+0.24	+0.20
June 19	+0.36	+0.28
July 13	+0.22	+0.28
August 19	+0.15	+0.19
September 19	+0.04	+0.06

Table II exhibits the observed displacement of 61 Cygni by monthly means as given by Main from Bessel's observations. The last column gives the computed displacement on the assumption of a parallax of 0″.314. The reality of the parallax is seen at a glance.

In 1888, fifty years after the first determination of what we now know to be a true stellar parallax, Young in his *General Astronomy* gives, in a list of known stellar parallaxes, 28 stars and 55 separate determinations. Within the next ten years the number of stars whose parallaxes had been determined about doubled, due principally to the work of Gill and Elkin.

Probably the most extensive piece of stellar parallax work in existence is that with the Yale heliometer. The results to date were published in 1912 and contained the parallaxes of 245 stars, the observations extending over a quarter of a century, the entire work having been done by three men, Elkin, Chase, and Smith. In selecting a list of stars for parallax work an effort is made to obtain stars which give promise of being nearer than the mass of stars. At first the brighter stars were selected, and then those with large proper motions. The Yale list of 245 stars contains all stars in the northern heavens whose annual proper motion is known to be as much as 0″.5. Of these 245 stars, 54 are given a negative parallax. A negative parallax does not mean, as some one has expressed it, that the star is "somewhere on the other side of nowhere," but such a result may be attributed to the errors of observation or to the fact that the comparison stars are nearer than the one under investigation. It is safe to say, however, that somewhat more than half of the 245 stars have a measurable parallax.

Another series of stellar parallax observations, comparable in extent with the one just mentioned, is that of Flint at the Washburn Observatory. This series includes 203 stars and extended from 1893 to 1905. These observations were made with a meridian circle, but not after the method of a century ago. The observations were strictly differential, the general plan being to select two faint comparison stars, one immediately preceding and the other immediately following the parallax star, and to determine the difference in right ascension, the observation of the three stars occupying about five minutes. Here as in the case of the Yale heliometer work a large proportion of the resulting parallaxes are negative; somewhat more than half, however, were found to have a measurable parallax. The

average probable error of a parallax was the same in each of these two pieces of work, about 0″.03. The progress of the work during the last two or three generations is given in Table III which contains also a brief statement of the discoveries made during the preceding century due chiefly to efforts to measure stellar parallaxes.

TABLE III

APPROXIMATE NUMBER OF KNOWN STELLAR PARALLAXES

DATE	ASTRONOMER	NUMBER OF STARS WITH KNOWN PARALLAXES	DISCOVERIES
1718	Halley	No parallax.	Proper motion.
1728	Bradley	No parallax.	Aberration.
1750	Bradley	No parallax.	Nutation.
1790	Herschel	No parallax.	True binary systems.
1838		3.	
1888		28.	
1898		50 to 60.	
1916		200 to 300.	

A generation ago photography entered the field of stellar parallax work, and has outdistanced all the previously employed methods for efficiency. In 1911, two publications appeared giving the results of photographic stellar parallax work, one by Russell, giving the parallaxes of forty stars from photographs taken by Hinks and himself at Cambridge, England, the other by Schlesinger, giving the parallaxes of twenty-five stars from photographs taken mostly by himself at the Yerkes Observatory, Williams Bay, Wisconsin. In speaking of these two series of observations, Sir David Gill said:

> On the whole, the Cambridge results, when a sufficient number of plates have been taken, and when the comparison stars are symmetrically arranged, give results of an accuracy which, but for the wonderful precision of the Yerkes observations, would have been regarded as of the highest class.

Schlesinger has shown that with a telescope of the size and character of the Yerkes instrument "the number of stellar parallaxes that can be determined per annum, with an average probable error of 0″.013, will in the long run be about equal to the number of clear nights available for the work."

In other words, the Yerkes 40-inch equatorial used photographically determines stellar parallaxes with one-tenth the labor required with an heliometer and with twice the accuracy.

In July, 1913, stellar parallax work was undertaken with the 60-inch reflector of the Mount Wilson Solar Observatory, and at the meeting of the American Astronomical Society at San Francisco in August, 1915 a report on that work was made. The parallaxes of thirteen stars had been determined, with a maximum probable error of 0″.010 and an average probable error of less than 0″.006, giving twice the accuracy of the Schlesinger results with the Yerkes 40-inch and from three to five times that obtained fifteen years ago. What may we not expect when the 100-inch reflector gets to work on Mt. Wilson.

At the meeting of the American Astronomical Society to which reference has just been made, two other observatories reported upon their stellar parallax work. Lee and Joy of the Yerkes Observatory reported the parallaxes of nine stars with a maximum probable error of 0.″014 and an average probable error of 0″.010, and Mitchell of Leander McCormick Observatory reported the parallaxes of eleven stars with a maximum probable error of 0″.012 and an average probable error of 0″.009.

The progress made in the accuracy of parallax results is shown at a glance in Table IV.

TABLE IV

THE ACCURACY OF STELLAR PARALLAX DETERMINATIONS

DATE		INSTRUMENT	PROBABLE ERROR	OBSERVERS
1838	Micrometric	Dorpat refractor	0″.025	Struve.
1838	Micrometric	Königsberg heliometer	0.02	Bessel.
1880–1898	Micrometric	Cape heliometer	0.017	Gill and Assistants.
1888–1912	Micrometric	Yale heliometer	0.03	Elkin, Chase, and Smith.
1893–1905	Micrometric	Washburn meridian circle	0.03	Flint.
1910	Photographic	Yerkes refractor	0.013	Schlesinger.
1915	Photographic	Yerkes refractor	0.010	Lee and Joy.
1915	Photographic	Leander McCormick refractor	0.009	Mitchell.
1915	Photographic	Mt. Wilson 60-inch reflector	0.006	Van Maanan

From these results it appears that any star whose parallax is as much as 0″.02, i.e., whose distance from the Earth is less than ten million times that from the Earth to the Sun, should give a positive result when subjected to the treatment now employed in parallax investigations, and as eight or ten observatories are devoting their energies to stellar parallax work at present, the combined programs containing over 1000 different stars, we ought soon to have lists of at least a few thousand stars whose parallaxes are known where our present lists contain but a few hundred.

OCEANOGRAPHY.—*On the temperature of the water below the 1000-fathom line between California and the Hawaiian Islands.*[1] AUSTIN H. CLARK, National Museum.

From October 11, 1891 until January 15, 1892 the United States Fisheries steamer *Albatross* was engaged in a cable survey between California and the Hawaiian Islands. On this cruise she occupied 556 stations (Nos. 2655 to 3202 in the records of the *Albatross* as published by the Bureau of Fisheries, Nos. 1 to 556 in the report published by the Navy Department), at nearly half of which the temperature of the bottom water was ascertained. Although these records are individually not so accurate as might be desired, it has seemed possible to make use of them by employing a system of broad averages; that is, by accepting as approximately true the mean of all the readings not obviously erroneous within units of five degrees of longitude.

Abyssal temperatures in the Pacific vary so slightly that if given in the actual figures it is difficult to appreciate the differences. The most graphic exposition of these differences is by presentation as plus or minus departures from the mean temperature for the whole ocean at the depths considered, as ascertained by comparison with the table published by Murray and Hjort.[2]

[1] Published with the permission of the Commissioner of the Bureau of Fisheries.

[2] Depths of the Ocean, p. xvi. 1912.

Using this method we find the following departures from the mean for the depth given between California and the Hawaiian Islands:

TABLE I

DEPTH (FATHOMS)	1000–1500	1500–2000	OVER 2000
120° to 125° W. long	−0°.20(3)*	−0°.25(6)	−0°.26 (7)
125° to 130° W. long			−0°.17 (23)
130° to 135° W. long			−0°.11 (11)
135° to 140° W. long			−0°.12 (24)
140° to 145° W. long			−0°.04 (16)
145° to 150° W. long			−0°.02 (15)
150° to 155° W. long		+0°.15(2)	+0°.15 (15)
155° to 160° W. long	±0 (1)		+0°.15 (9)
Maximum variation	0°.20	0°.40	0°.41

* The numbers in parentheses are the numbers of observations.

Below 2000 fathoms we find a maximum variation of only 0°.41 Fahrenheit. The abyssal water is coldest on the California coast; it gradually becomes warmer to long. 130°–140°W., then becomes gradually warmer again at almost the same rate to long. 145°–160°W., from which point it becomes rapidly warmer to long. 150°–160°W. The water between 1000 and 2000 fathoms is also warmer about the Hawaiian Islands than on the Californian coast. (See fig. 1.)

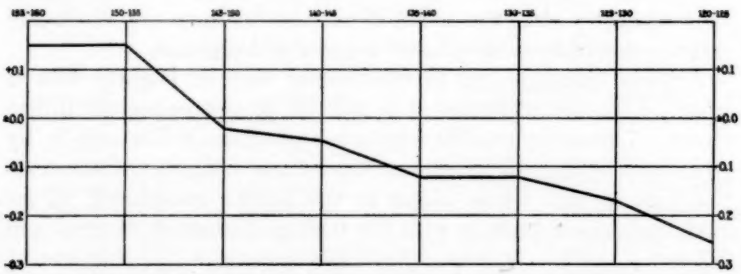

FIG. 1. Diagram illustrating the increase in the temperature of the water below 2000 fathoms between California and the Hawaiian Islands. The temperatures, recorded as plus or minus departures from the mean of the ocean as a whole, are given as averages of all the observations for each five degrees of longitude.

On the basis of the data it would be hazardous to attempt any generalizations; but the regular sequence of the figures suggests that in spite of the individual variation of the observations the averages are more or less reliable, and that the warming of the abyssal water from the Californian coast toward the mid-Pacific may be accepted as a fact.

In this connection it is well to call attention to the relatively high abyssal temperatures on the South and Central American coasts, as contrasted with those from southern California northward, especially off southern California and in the Gulf of Alaska.

PHYSICS.—*Plastic flow.*[1] E. C. BINGHAM, Richmond College. (Communicated by C. W. WAIDNER).

Bingham and Durham[2] showed experimentally that the fluidity of a suspension is a linear function of the concentration. The zero of fluidity is reached at a comparatively low volume concentration, as is shown in figure 1. The concentration which has zero fluidity serves to sharply demarcate viscous from plastic flow. All concentrations less than this are viscous and any shearing force, no matter how small, will produce a permanent deformation if exerted long enough. Concentrations greater than this are plastic and it is necessary to use a shearing force of definite magnitude in order to produce a permanent deformation. The laws of plastic flow have never been studied. The method of attack was to force suspensions of clay in water under known

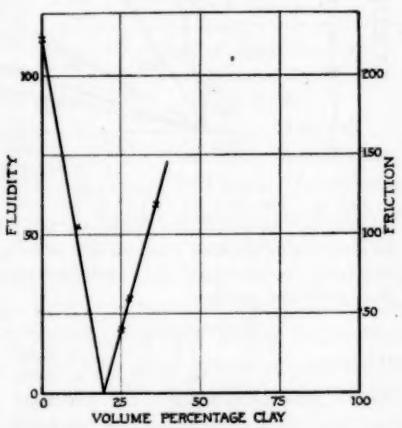

FIG. 1. Relation of fluidity and friction to concentration.

[1] This work has done at the Bureau of Standards.

[2] Amer. Chem. Journ. **46**: 278. 1911.

pressure through capillaries of different dimensions and measure the rates of flow. Some of the values obtained are shown in figure 2. For medium pressures the volume of flow is given

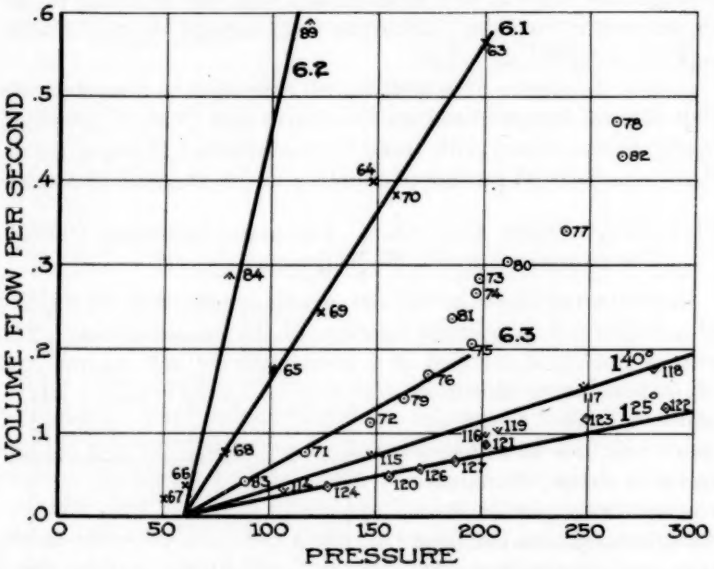

FIG. 2. The flow (in cc.) of 50 per cent clay suspension in water containing 0.1 per cent of potassium carbonate in solution, for pressures (g. per sq. cm.) as shown, and at 25°C., except one series of experiments with Capillary No. 1 which was made at 40°C. The following are the numbers and dimensions of the capillaries used:

Number of Capillary	*Radius in cm.*	*Length in cm.*
1.0	0.02848	2.468
6.1	0.05785	5.011
6.2	0.05811	2.509
6.3	0.05850	9.998

by the formula $v = k\ (P - f)$, where P is the pressure employed and f is the "friction," *i.e.*, the force required to start the flow. Putting $(P - f)$ in place of P in the ordinary Poiseuille formula for calculating the fluidity, we have a means for calculating the "mobility" of plastic substances, analagous to the

fluidity of viscous substances. The friction increases as a linear function of the concentration of solid present (fig. 1). It is independent of the length and diameter of the capillary and of the viscosity of the medium. It is, however, affected by the presence of alkalies or acids in the medium. The mobility decreases rapidly as the concentration of the solid is increased, as is seen in figure 3. The mobility is enormously sensitive to the presence of alkalies or acids, the mobility of a neutral clay suspension being increased 330 per cent by the addition of 0.1 per cent of potassium carbonate. At pressures little if any greater than those necessary to overcome the friction there was detected a seepage of the medium past the solid particles (see capillary 6.1, fig. 2). At high pressures there was sometimes a sudden increase in the rate of flow, which is apparently due to slipping (see capillary 6.3, fig. 2). If the solid material consisted of spheres of equal size, the pore space left when the spheres were as closely packed as possible would amount to about 26 per cent, quite irrespective of the radius of the spheres. However, due to the friction of the spheres on each other, the pore space may be larger than this, and this is particularly true if the material is finely divided. As a matter of fact, it was found that on shaking dry clay into a flask the pore space amounted to 81.6 per cent of the total volume. This corresponds closely to the percentage of liquid present in the mixture having zero fluidity, which is 80.5. It is upon this friction that plasticity depends and the plasticity is thus closely related to the fineness of subdivision of the material.

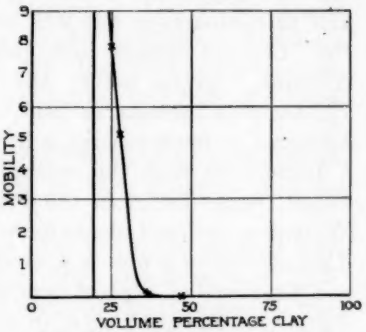

FIG. 3. Relation of mobility to concentration.

GEOLOGY.—*Note on a recent discovery of fossil plants in the Morrison formation.*[1] F. H. KNOWLTON, Geological Survey.

There has been a good deal of discussion within the past few years regarding the stratigraphic position of the Morrison formation, that is, as to whether it should be placed in the upper part of the Jurassic or the lower portion of the Cretaceous. The divergence of opinion on this point among stratigraphers and paleontologists was well brought out in the symposium on the "Close of Jurassic and opening of Cretaceous time in North America," given before the Paleontological Society at the Philadelphia meeting in 1914,[2] though the concensus of opinion appeared to favor placing it in the Cretaceous.

Heretofore, with the exception of some 20 nominal species of cycad trunks found in the Freezeout Hills in Carbon County, Wyoming, no fossil plants have been reported from the Morrison. This deficiency is now in a small measure supplied by the fortunate discovery of a plant-bearing horizon in the Morrison near Little Cottonwood Creek, in the eastern part of Bighorn Basin, Wyoming. Mr. C. T. Lupton, of the United States Geological Survey, found this locality in 1915 and sent in a small collection. Mr. Lupton has kindly supplied me with the following data regarding the location and stratigraphic relations:

> The fossil leaves I sent in were collected by my assistant, Mr. E. M. Parks, in the NW. ¼ sec. 14, T.47 N., R. 89 W., on the east side of Little Cottonwood Creek, an intermittent tributary of No Wood River. This place is about 5 miles west slightly north of the town of Ten Sleep, and about 1½ miles north of the Worland-Ten Sleep road where it crosses the former stream.
>
> The leaves occur in a thin bed of light shaly sandstone which lies just beneath a prominent 50-foot bed of white ledge-making sandstone containing a little conglomerate at its base. This prominent sandstone is variable in thickness and constitutes the basal part of the Cloverly formation as identified by Darton. The varicolored beds below this conglomeratic sandstone are characterized in many places by gastroliths ('stomach-stones').

[1] Published with the permission of the Director of the U. S. Geological Survey.

[2] Papers by Osborn, Lee, Mook, Lull, Berry, and Stanton. Bull. Geol. Soc. America **26**: 295–348. 1915.

The matrix in which the plants is preserved is a white, fine-grained, shaly sandstone, well fitted to retain the details of nervation, and there can be no question as to the identification. The two species present are: *Nilsonia nigricollensis* Wieland[3] and *Zamites arcticus* Göppert.[4] The first species has previously been found only at its type locality in the lower part of the Lakota sandstone, near the summit of the Black Hills rim, 5 miles north of Sturgis, South Dakota. The other species (*Zamites arcticus*) is very abundant in the Kootenai of Montana, and several Canadian localities. It has been reported also from the so-called Shasta flora of California, and from the Kome (Urgonian) of Greenland.

While it is manifestly unsafe to build much of a generalization on two species, yet so far as they go they indicate that the Morrison is Cretaceous.

A word may be added as to the evidence to be derived from the cycad trunks above mentioned from the Freezeout Hills. Although they are referred to a distinct genus (Cycadella) they are certainly very close to, if not indeed identical with, similarly silicified trunks of the genus Cycadeoidea, which are so abundant in the Lakota sandstone of the Black Hills rim and which occur also in the Patuxent formation of Maryland. The internal structure has not been fully investigated in Cycadella, about the only obvious difference between it and Cycadeoidea being the profusion of ramentum in the former, which is a character of doubtful generic value. This evidence also—so far as it goes—argues for the Cretaceous age of the Morrison.

MINERALOGY.—*The lozenge-shaped cavities in the First Watchung Mountain zeolite deposits.* EDGAR T. WHERRY, National Museum.[1]

The zeolite deposits in the basalt of First Watchung Mountain in Passaic County, New Jersey, frequently contain angular cavities representing minerals which crystallized out at an

[3] WIELAND, G. R., in WARD: U. S. Geol. Survey Mon. 48, 319, pl. 73, figs. 15a–d. 1905.

[4] Op. cit., 306, pl. 73, figs. 1–6.

[1] Published by permission of the Secretary of the Smithsonian Institution.

early stage, became surrounded by quartz, prehnite, or zeolites, and at some subsequent time dissolved away. Replacement by quartz also took place at various stages in the history of these crystals, so that the cavities sometimes show lamellae where the quartz entered along cleavage planes, and in other cases have been completely filled by quartz, occasionally yielding a removable core. Two types of crystals are represented, one rectangular in outline, thick to thin tabular in habit, and evidently orthorhombic, the other lozenge or "diamond"-shaped in cross section, prismatic in habit, and monoclinic in symmetry.

Babingtonite was suggested by Dr. C. N. Fenner[2] as the original mineral of the rectangular cavities, and possibly of the lozenge shaped ones as well, while Mr. F. I. Allen[3] has shown that anhydrite was the original occupant of the former in many cases. Reasons are here presented for believing the mineral of the lozenge shaped cavities to have been glauberite, $Na_2Ca(SO_4)_2$.

In connection with studies of the Triassic rocks of the eastern United States the writer has long been interested in the angular cavities occasionally found in the shales, and while examining specimens of these from one mile south of Steinsburg, Bucks County, Pennsylvania, obtained a clue to the nature of the original mineral. Plaster casts of the well-preserved cavities in this shale were prepared, and found to have the angles, habit, and type of oscillatory combination of faces, resulting in striations and rounding of faces, characteristic of glauberite. No trace of the original mineral is here preserved; but in another occurrence, described by Mr. A. C. Hawkins,[4] the crystallization of the mineral in the muds in downward-radiating groups of long slender monoclinic (or triclinic) prisms and the filling of its cavities by secondary analcite and calcite (which contain sodium and calcium respectively) indicate that the original mineral here also was probably glauberite.

Comparison of the lozenge-shaped, prismatic cavities in the First Watchung Mountain zeolites with glauberite thereupon

[2] Journ. Wash. Acad. Sci. **4**: 552–558, 598–605. 1914.
[3] Amer. Journ. Sci. **39**: 134. 1915.
[4] Ann. N. Y. Acad. Sci. **23**: 163. 1914.

suggested itself, and the angles, habit, and curvature of faces (due to oscillatory combination) of plaster casts of a few of them were found to be essentially identical with those of glauberite.[5] That glauberite has not been considered in this connection before is probably due to the fact that the crystals figured in Dana's *System of Mineralogy* happen to be all of tabular habit, although, as noted in the text, this species is not infrequently prismatic, owing to the extension of the form *s*. This form is usually regarded as the unit pryamid, but it may well be questioned whether it might not be made the unit prism.[6] The forms which have been observed on the cavities in the zeolites are *c* (100), $a(334)$, $\epsilon(445)$, $s(111)$, $m(110)$, $a(100)$, and $e(\bar{3}11)$; the most important angles are $s \wedge s'$ 63°42′ (the prismatically developed form), $c \wedge s$ 43° 2′, $c \wedge a'$ 112°11′, $s \wedge \epsilon$ 4°55′, $s \wedge \alpha$ 6°21′, and $a' \wedge e$ 31°42′, variations of several degrees owing to the oscillatory combination of forms being frequent in these angles, a phenomenon observed also in many crystals of the mineral.

The identification of the mineral of these cavities as glauberite, though based primarily on crystallographic data, is confirmed by geological and genetic considerations. At Steinsburg and at Princeton the mineral crystallized in the sediments as a result of concentration of the water in enclosed lakes. Most of the known occurrences of this mineral are in this sort of deposit, and it is always one of the earliest to form. The basalt lava of the First Watchung Mountain, as shown by Dr. Fenner,[7] flowed locally into a similar lake, the waters of which contributed to the formation of the zeolites and other minerals and could readily have furnished the calcium sulphate of the anhydrite and the additional sodium sulphate of the closely associated glauberite. It is noteworthy that glauberite has been observed,[8]

[5] Dr. W. T. Schaller of the U. S. Geological Survey has made an extensive series of measurements of the angles of the quartz "cores" found in some of the cavities, and he kindly lent his notes to the writer for comparison; complete agreement with the artificial casts was shown.

[6] In a subsequent paper this new orientation of the mineral will be fully discussed by Dr. Schaller.

[7] Ann. N. Y. Acad. Sci. **20**: 93–187. 1910.

[8] BERGEAT. Zeit. prakt. Geol. **7**: 43. 1899.

on the island of Vulcano, in fumarole deposits, which are genetically related to these "zeolite-veins." There is also a quite analogous occurrence of this mineral at Rosenegg, Württemberg, the igneous rock being in that case a phonolite tuff, while the glauberite has been replaced by both calcite and quartz.[9]

Summary: The lozenge-shaped, prismatic, monoclinic cavities which occur in Triassic shales and especially in the First Watchung Mountain zeolite deposits are believed to represent the mineral glauberite, the crystallographic, geological, and genetic evidence all pointing in the same direction. A full report on this subject, with descriptions of the geologic occurrences, the crystallographic measurements, figures of specimens, etc., is in preparation.

[9] LEUZE. Jahresh. Ver. vaterl. Naturk. Württemberg 1886, 62; 1889, 305; abstracted in Zeit. Kryst. Min. **14**: 408. 1888; **20**: 303. 1892.

ABSTRACTS

Authors of scientific papers are requested to see that abstracts, preferably prepared and signed by themselves, are forwarded promptly to the editors. Each of the scientific bureaus in Washington has a representative authorized to forward such material to this journal and abstracts of official publications should be transmitted through the representative of the bureau in which they originate. The abstracts should conform in length and general style to those appearing in this issue.

CHEMISTRY.—*The colorimetric determination of acetylene and its application to the determination of water.* E. R. WEAVER. Bureau of Standards Scientific Paper No. 267. Pp. 39. 1916.

A colorimetric method for the detection of small amounts of acetylene has been developed in the course of an investigation upon the determination of small amounts of water by the use of calcium carbide. The results upon the quantitative determination of water have not been satisfactory, but a simple and very sensitive qualitative test for water is easily made.

The method for the determination of acetylene has been worked out successfully. The determination is made by conducting the gas to be investigated into an ammoniacal solution of cuprous chloride containing gelatine and alcohol, and comparing the red colloidal solution so obtained with a suitable standard, which may be either a solution of red dye or a piece of ruby glass.

The method is very sensitive. Amounts of acetylene as small as 0.03 mg. may be detected and amounts up to 2 mg. may be determined with an accuracy of better than 0.05 mg.

Hydrogen sulphide and large amounts of oxygen and carbon dioxide interfere with the test, but all of these may be removed by passing the gas to be tested through a hot alkaline solution of pyrogallol without loss of acetylene.

A qualitative test for water, sensitive to less than 0.1 mg., may be very easily and quickly made by bringing the substance to be tested into contact with calcium carbide in the presence of a solvent for acetylene, which is then decanted or distilled into an ammoniacal solution of cuprous chloride. E. R. W.

PALEONTOLOGY.—*Bibliographic index of American Ordovician and Silurian fossils.* RAY S. BASSLER. U. S. National Museum Bulletin 92. Pp. 1521, 4 pls. (tables). 1915.

This work gives the entire bibliography and synonomy of the hundreds of genera and thousands of species found in North America in the rocks of the Ordovician and Silurian periods. In addition, the genotypes of the genera are given, and also the formation, the type locality, and the known wider distribution of the species. In cases where the U. S. National Museum has type material, this is noted and the Museum catalog numbers are cited. At the end of the bibliography proper is given an index of specific names and their generic combinations (pages 1342–1406), a bibliographic classification and index of genera (1407–1440), faunal lists of American Ozarkian to lowest Helderbergian species (1441–1509), and a list of American Ordovician and Silurian formations showing their place in the geologic column (1511–1521). Finally at the end of the work are four very important correlation tables of the geologic divisions and their occurrence in the various basins of deposit. R. S. B.

ANTHROPOLOGY.—*Kickapoo tales.* WILLIAM JONES and TRUMAN MICHELSON. Publications of the American Ethnological Society, **9**: 1–143. 1915.

The texts of these tales were collected by the late William Jones in 1903; the translations are nearly all by Truman Michelson, as are all the comparative notes. The notes on Kickapoo grammar are based mainly on the materials left by William Jones, edited by Truman Michelson, though some observations by the latter have also been incorporated. The notes on the conditions of the texts are likewise by the latter.

The tales are, so far as is known, the first extended publication of Kickapoo folk-lore. They are eleven in number: three Culture Hero tales, three Animal tales, and five miscellaneous tales. A comparative study shows that both woodland and plains elements occur. The question as to which predominates cannot be answered until more material is available. That European elements also occur is clear. Tentatively we may say that Kickapoo folk-tales and mythology are closest to Fox, which is in accordance with the linguistic facts. T. M.

PROCEEDINGS OF THE ACADEMY AND AFFILIATED SOCIETIES

THE PHILOSOPHICAL SOCIETY OF WASHINGTON

The 768th meeting was held on February 19, 1916, at the Cosmos Club; President BRIGGS in the chair, 41 persons present. The minutes of the 767th meeting were read in abstract and approved.

Mr. WILLIAM BOWIE presented an illustrated paper on *Determination of the intensity of gravity on land in the United States.* Numerous attempts have been made to determine accurately the absolute gravity by the reversible pendulum, but the results were not very satisfactory for there were a number of errors which entered into the determination. The principal ones were probably in the determination of the distances between the two knife edges on the pendulum, the flexure of the pendulum support, and the temperature changes. Later attempts were made by using the invariable pendulums which were swung only in the direct position, the period being determined at the base station and then at the new station. Since the length of the pendulum is invariable, the difference in gravity at the two stations could be obtained by a simple formula involving only the two periods. Because of the great length of the second pendulum used at first, great accuracy was not obtained from the observations. A great step forward was made when Baron von Sterneck of Vienna designed and constructed the half-second invariable pendulum which he swung in a closed case from which the air had been almost entirely exhausted. These pendulums give a high degree of accuracy in the determination of the relative intensity of gravity at any two stations. All the gravity determinations in the United States during the last 25 years have been made with the Mendenhall pendulum, which is a modification of the von Sterneck pendulum, and the results have been most satisfactory. The value of the intensity of gravity at each station in the United States has been corrected for topography and isostatic compensation, as well as for elevation above sea level. The resulting anomalies (the differences between the observed and computed values) are small in comparison with the anomalies obtained by the older methods which are not based upon the theory of isostacy.

Discussion: Mr. SWANN asked whether the proposed use of invar in the construction of the pendulum would not require correction for magnetization. Mr. HUMPHREYS stated that some invars were practically non-magnetic. Mr. ABBOT asked how much time was required to make a satisfactory determination. Mr. C. A. BRIGGS thought that

the transfer of the knife edges from the pendulum to the support would introduce inaccuracies. Mr. Bowie stated that, on the average, 4 stations were occupied per month; the transfer of knife edges from the pendulum to the support causes no sensible error.

Vice-President HUMPHREYS took the chair and Mr. L. J. BRIGGS then presented an illustrated communication on *Measurement of the acceleration of gravity at sea*. The different methods which have been proposed and used in the measurement of the acceleration of gravity were first discussed. Two other methods, the first based on the current-balance and the second on the viscosimeter, were suggested. The speaker then presented a series of gravity measurements at sea from New York to San Francisco via Panama with instruments of the type already used in trans-Pacific measurements; in this type the pressure of an inclosed mass of gas is balanced by a column of mercury of variable height. The apparatus is so designed that the volume of gas is constant at the time of making the observations and, since the temperature is maintained constant by a bath of melting ice, the heights of the mercury column at two stations are theoretically inversely proportional to g at the two stations. The average probable error of the mean of the readings of 3 instruments at base stations on the voyage from New York to San Francisco was 1 part in 60,000. Apparent anomalies were observed at sea on both sides of the Isthmus, off the coast of Lower California, and off the California coast near San Francisco.

Discussion: Mr. SWANN stated that one should expect systematic differences for observations during rough weather because of the effect of centrifugal action on the mercury column and called attention to a possible method for compensation. Mr. BOWIE thought that the results presented indicated a decided improvement in the accuracy of determination at sea over previous work; along the shallow waters near the coast the errors doubtless would be greater than those due to topography, but over the deep-sea areas the data obtained should be valuable. Mr. ABBOT asked how much time was required for observations at base stations. Mr. CURTIS referred to the difficulties experienced with reference to designation of units for gravity work. Mr. WHITE referred to possible improvements in details of contruction of the apparatus. Mr. BRIGGS stated that he thought further improvement could be effected by exercising greater precaution with reference to the cleaning of the mercury and the apparatus before sealing.

The 769th meeting was held on March 4, 1916, at the Cosmos Club: President BRIGGS in the chair, 68 persons present.

The evening was devoted to the address of the retiring President, Mr. W. S. EICHELBERGER, *The distances of the heavenly bodies*. (This Journal, pp. 161–175).

J. A. FLEMING, *Secretary*.

THE GEOLOGICAL SOCIETY OF WASHINGTON

The 302d meeting was held in the lecture room of the Cosmos Club on January 12, 1916.

INFORMAL COMMUNICATIONS

MAX W. BALL exhibited photographs of the results of an earthquake which occurred about 50 miles south of Winnemucca, Nevada. The pictures were taken by S. L. Gillan, Mineral Inspector, General Land Office.

REGULAR PROGRAM

T. WAYLAND VAUGHAN: *Some littoral and sub-littoral physiographic features of the Virgin and Leeward Islands. A discussion of submarine terraces, their significance, the criteria for determining their relative age, and their relation to the development of coral reefs.* Illustrated. (Published in full in Journ. Wash. Acad. Sci. **6**: 53–66. 1916.)

O. E. MEINZER: *Physical features of Guantanamo Bay and adjacent areas in Cuba.* The rocks in the region comprise: (1) a basal complex of metamorphic and igneous rocks; (2) a sedimentary series, several thousand feet thick, consisting chiefly of conglomerate, limestone, and shale resting unconformably on the basal complex and in general dipping away from its outcrops; (3) horizontal beds of conglomerate and coralline limestone underlying a series of terraces and resting unconformably on the basal complex and on the tilted beds of conglomerate, limestone, and shale; (4) stream gravels; and (5) recent marine and delta deposits. Fossils collected in 20 localities have not yet reached Washington. Four marine terraces are well developed—in most of the region at altitudes of about 40, 200, 500, and 750 feet. They consist largely of benches cut into the older rocks (Series 1 and 2) and mantled with coralline limestone (Series 3). Their development in the interior valleys indicates that the present major topographic features were in existence prior to the terraces. They rank in age according to their altitudes. All bear evidences of geologic youth and were apparently formed in the Quaternary period. After the 40-foot terrace was formed the region stood higher than at present, as is indicated by innumerable small bays and estuaries which were created through the dissection of the 40-foot terrace limestone, and by a submerged bench (or series of benches) 100 feet or less below present sea level. That the shore line has for a long time been stationary is shown by the existence of a well-developed bench at present sea level.

G. S. ROGERS: *Oil field waters and their chemical relations to oil; particularly the conversion of sulphates into carbonates by hydrocarbons.* It has long been known that oil and gas are commonly associated with water, but of the chemical relations between the two we know little, and scientific literature contains only a few references to the chemical composition of the waters themselves. The study of several hundred analyses of water from the oil fields of the San Joaquin Valley, Cali-

fornia, discloses the following facts. (a) Some of the deepest waters are as salty as sea water, while in others chlorides are practically lacking. The distribution of the chlorides is apparently a function of the freedom of the underground circulation, which is controlled largely by geologic structure. (b) Sulphates, which are the predominating salts in the normal ground water on the west side of the San Joaquin Valley, diminish rather regularly in amount as the oil zone is approached and finally disappear, but outside of the oil fields their quantity remains constant to great depths or even increases. (c) Carbonates increase as the oil zone is approached, and if no chlorides are present constitute the only dissolved salts in the waters associated with the oil.

These marked variations in the character of the waters are presumably due to reaction between them and the hydrocarbons, by which the sulphate is reduced to H_2S and the hydrocarbons oxidized to carbonate and CO_2. Carbon dioxide, doubtless derived in this way, is present in the hydrocarbon gas in these fields and usually occurs in greatest quantity (up to 35 per cent) nearest the outcrop, where the sulphate waters enter the strata and where the reaction would be most vigorous. It is probable also that part of the H_2S formed is oxidized to sulphur, which would react with the oil and make it heavier and more asphaltic. In general, the heaviest oil is that nearest the outcrop and that in the zone of "tar sands" above the main oil zone, where the sulphate water would exercise its greatest effect. The occurrence of the heavier oil nearest the surface has hitherto been ascribed to oxidation, but the action of sulphur derived from the sulphate waters is believed to have been more important.

The 303d meeting was held in the lecture room of the Cosmos Club on January 26, 1916.

REGULAR PROGRAM

G. F. LOUGHLIN: *Faulting in the Tintic Mining District, Utah.* Five periods of faulting are recognized: (a) faulting during the later stages of the period of folding; (b) faulting during the subsequent period of recoil; (c) faulting due to igneous intrusions, especially that of the main monzonite stock; (d) fissuring and faulting just after igneous intrusion, providing channels for the ore-forming solutions; (e) post-mineral fissuring and faulting. The largest faults in the mining district proper are included in groups (a) and (c). They had only minor influence in determining the locations of ore bodies.

A detailed discussion of the faulting will be included in a forthcoming report of the United States Geological Survey on the geology and ore deposits of the Tintic District.

PHILIP S. SMITH: *Notes on the geology of the Lake Clark-Iditarod region, Alaska.* The speaker described the areal geology of the Lake Clark-Iditarod region, Alaska. This region is located in southwestern Alaska, extending from the Pacific Mountains to the central part of the Yukon Plateau province. The rocks are dominantly sedimentary

strata of Mesozoic age, but some Paleozoic limestones are also exposed. Igneous rocks both of intrusive and effusive origin occur at a number of places and certain of them seem to have been closely associated with the deposits of commercial value such as gold and quicksilver. Unconsolidated deposits are widespread and throughout much of the region mantle and hide the underlying bedrock. These deposits are mainly of glacial and glacio-fluviatile origin, though lacustrine, fluviatile, and volcanic ash deposits are also described.

F. W. CLARKE: *The inorganic constituents of marine invertebrates.* Two hundred analyses of hard parts of corals, mollusks, echinoderms, worm tubes, algae, etc., throw much light on the origin of magnesian limestone and phosphatic rock. (No abstract; the complete paper will be published as a Professional Paper of the U. S. Geological Survey).

CARROLL H. WEGEMANN, *Secretary.*

THE BOTANICAL SOCIETY OF WASHINGTON

The 111th regular meeting of the Botanical Society of Washington was held in the Crystal Dining Room of the New Ebbitt Hotel, Wednesday evening, March 8, 1916. Eighty-two members and 117 guests were present. Mr. A. S. HITCHCOCK, president of the Society, presided. Dr. RODNEY H. TRUE, as retiring president, delivered an address, an abstract of which is given below. A dinner preceded the address, after which there was dancing.

Relation of Thomas Jefferson to Botany: RODNEY H. TRUE. It is not generally known that THOMAS JEFFERSON, who was perhaps the center of a more intense partisan activity than any other man of his time, was at the same time a great lover of outdoor life and took a keen interest in an amateur way in botany. Throughout his life he maintained a correspondence with many of the prominent botanists of his time and exchanged garden plants with WILLIAM HAMILTON, BERNARD MCMAHON, JOHN BARTRAM, and other gardening botanists. Like many of his planter neighbors, Jefferson accumulated a rather extensive collection of rare and interesting plants and built up what was perhaps one of the best botanical libraries in the United States. He wrote only one book dealing chiefly with matters of science, his *Notes on Virginia*, printed while he was in France in 1784. This book dealt with the State of Virginia in all its aspects and in proper chapters discussed the botany and natural history of the state. This book was translated into the French and German languages and ran through many editions during the first fifty years of our country's history. While in France he kept in close touch with the various developments of European science and wrote long letters to various American correspondents, including friends at Harvard, Yale, and other institutions, summarizing the most important results coming to his attention. His belief that the future of the United States was closely connected with the country beyond the Mississippi led him to endeavor to secure the exploration of that country soon after the close of the Revolution.

But it was not until he received authority to launch the Lewis and Clark expedition that he was able to achieve his object. He planned the expedition with the greatest of care, appointed chief officers, gave them very detailed instructions concerning what they should attempt to do, and after the return of the expedition was finally successful in getting the results collected for publication. After his retirement to Monticello he maintained an active correspondence with many botanists and other scientists on the important scientific questions then under consideration. In his old age he was the means of securing the appropriation making possible the University of Virginia. He was made head of the institution, planned its buildings, supervised their construction, chose the faculty, and determined the policy of this great state institution. It seems clear that, notwithstanding the prominent position which Jefferson attained in the political life of his country, he was also an important figure in the American scientific world of his time.

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